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Does Internal and External Research and Development Affect Innovation of Small and Medium-Sized Enterprises? Evidence from India and Pakistan

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Abstract

This study investigates the impact of internal and external research and development (R&D) on the innovation performance of small and medium-sized enterprises (SMEs) in India and Pakistan. Micro-level data was obtained for 3,492 Indian and 696 Pakistani SMEs from the World Bank's Enterprise Survey, and bivariate probit estimation techniques were used. The results show that internal and external R&D positively affects product and process innovations. However, this effect is stronger for Indian SMEs. The negative relationship between firm size and innovation output implies that SMEs in both countries face resource constraints. Further, Indian SMEs are dominant in terms of undertaking internal R&D and generating product and process innovations relative to those in Pakistan. The complementary relationship between internal and external R&D has been examined for both countries. The study is unique in comparing Indian and Pakistani SMEs innovation activities using micro-level data. The results suggest that business managers can utilize a balanced combination of internal and external R&D to accelerate innovation output and increase absorptive capacity. Specifically, public support for innovation, such as R&D grants, subsidies, and tax credits, could encourage SMEs to undertake more radical innovations.

JEL Classification: D22, L25, O31, O32

Contents

1. INTRODUCTION

Innovation is an expensive and risky activity. From a firm's perspective, innovation can be defined as a complex process involving new ideas—their development, transformation, and application—using knowledge technologies, capabilities, and resources (Karlsson and Tavassoli 2015; Artz et al. 2010). Similarly, a firm engaged in innovation activities is involved in many complex strategies (e.g., product, process, marketing, and organizational innovation) because innovation plays a key role in the evolution of industries. Studies single out innovation as a primary driver of firm competitiveness and the ultimate source of productivity and growth (Karlsson and Tavassoli 2015; Subrahmanya 2012). Not surprisingly, firms carry out innovation by internal (internal R&D) and external (R&D collaboration) efforts and have better technological strength to produce product and process innovations because investment in innovation enhances the technological advancement and minimizes the firm's marginal cost of production (Ganotakis and Love 2011).

Small and medium-sized enterprises (SMEs) are a driving force in advanced economies due to their multifunctional contributions to employment, exports, and technological innovation. SMEs' flexibility, adaptability, effective internal communication, and quick decision making can provide them with a competitive edge over large firms. However, several studies (Conte and Vivarelli 2013; Love and Roper 1999; Subrahmanya 2012) have found that SMEs are more financially and nonfinancially constrained than large firms. A lack of financial assets, weaker competencies, reduced absorptive capacity (to internalize external knowledge), and the absence of economies of scale force SMEs to underinvest in R&D. Likewise, Demirbas et al. (2011) argue that SMEs operating in developing countries often face extra barriers such as lack of technological investment, a low level of R&D, and skills shortages. Presently, the global challenges for SMEs' survival are related to promoting an innovative culture, improving the quality of innovation (i.e., radical innovations that are supported by R&D), and encouraging patenting culture for superior SME performance. Empirical studies suggest that SMEs can use internal R&D coupled with external R&D to significantly improve innovation performance (Ceccagnoli et al. 2013).

Open innovation models suggest that SMEs can achieve innovation through internal or external knowledge and technologies (Spithoven et al. 2013). Internal R&D alone is not sufficient and SMEs' use of external R&D is equally important to achieve higher levels of innovation. Numerous empirical studies have emphasized the importance of internal and external R&D for product and process innovation output (Cohen and Levinthal 1989; Stam and Wennberg 2009; Añón-Higón et al. 2015; Hagedoorn and Wang 2012). Cohen and Levinthal (1989) suggested that internal R&D not only generates product and process innovation but also improves firms' absorptive capacity (i.e., learning effect). Similarly, Lane and Lubatkin (1998) argued that external R&D increases a firm's innovative output and absorptive capacity if these small firms are reluctant to invest alone in R&D.

The major contribution of this paper lies in the unique data set used, which comprises firm-level cross-sectional data and allows for comparative analysis of Indian and Pakistani SMEs. To the best of the author's knowledge, very few empirical studies are available on the innovation performance of Indian and Pakistani SMEs. This study seeks to fill the research gap. The study investigates, for the first time, the complementary relationship between internal and external R&D among Indian and Pakistani SMEs.

The results show that SMEs engaged in internal and external R&D are more likely to introduce product and process innovations. However, this effect is found to be stronger for Indian SMEs. Pakistani SMEs are less innovative than Indian SMEs in terms of undertaking R&D and generating product and process innovation. In addition, the probit models show that internal and external R&D have a complementary relationship.

2. THEORY AND HYPOTHESES

2.1 Internal Research and Development

R&D is an important intangible input asset that is significantly associated with firm innovation. Innovation results from investment in R&D (Czarnitzki and Hottenrot 2011) because R&D increases a firm's stock of knowledge and a firm can utilize that knowledge to introduce new products (Artz et al. 2010). Similarly, several researchers have identified R&D as a major innovation input for increasing firms' innovation performance (Conte and Vivarelli 2013; Pellegrino et al. 2014; Karlsson and Tavassoli 2015; Hall and Bagchi-Sen 2002). Regarding the role of R&D, numerous studies state that R&D performs two major functions: (i) it generates new knowledge through product and process innovation, and (ii) it increases the firm's absorptive capacity (Cohen and Levinthal 1989; Stam and Wennberg 2009; Gallie and Legro 2012; Ceccagnoli et al. 2013).[1] In other words, R&D not only introduces technological competencies, but it also helps the firm to absorb knowledge spillovers from external sources. This suggests that R&D is an important indicator for measuring a firm's absorptive capacity (Gallie and Legros 2012). However, R&D is a costly and risky investment and requires a long-term commitment if it is to improve the firm's competitiveness and innovation performance (Pradhan 2011, Ortega-Argiles et al. 2009). SMEs normally carry out informal (or nonpermanent) R&D by using resources from different departments due to lack of financial and technological competencies.

SMEs generally tend to underinvest in R&D because of higher uncertainty in the success of innovative projects and the lack of information between the firm and external suppliers of finance. Further, small firms have limited access to internal and external finance as they cannot use their initial money and profits to invest in risky projects (Czarnitzki and Delanote 2015). Sometimes, it is less expensive to imitate than to innovate because firm size is correlated with the availability and stability of internally generated funds (Ortega-Argiles et al. 2009). It is argued that investment in R&D below the optimal level is very expensive and R&D subsidies and grants can alleviate the underinvestment in innovation activities (Meuleman and Maeseneire 2012). Czarnitzki and Delanote (2015) conducted a study on 3,272 German SMEs and concluded that R&D subsidies significantly boost innovation performance. A study by Hottenrott and Lopes-Bento (2012) of 1,973 Belgian SMEs also found that R&D subsidies accelerate R&D spending and have a significant impact on firms' innovation performance. Orteg-Argiles et al. (2009) too suggested that fiscal incentives and subsidies for SMEs may overcome the problems of weaker competencies, reduced absorptive capacity, and the absence of economies of scale In yet another study, Demirbas et al. (2011) analyzed the barriers to innovation for 224 Turkish SMEs using a logit model. They found that lack of government support for R&D significantly reduces

[1] Similarly, Ornaghi (2006) states that R&D generates two types of externalities: rent spillovers (e.g., investment in goods, patent licensing, and quality improvements), and knowledge spillovers (exchange of information at conferences and reverse engineering).

innovation performance. This indicates that R&D is essential input for SME innovation, because it significantly improve the SME innovation output (Parrilli and Elola 2012).

Furthermore, Artz et al. (2010) conducted a panel study of US firms and found that R&D has a positive and significant impact on firm invention (patents) and innovation (new products). Mairesse and Mohnen (2005) examined the positive relationship between R&D and product and process innovation using tobit regression analysis on 2,253 French firms. Similarly, Ganotakis and Love (2011) conducted a study on 412 SMEs in the United Kingdom (UK). They revealed that internal R&D has a strong and positive impact on firms' product innovation. Gallie and Legros (2012) analyzed French firms by using unbalanced panel data and found that R&D has significant and positive impact on firms' innovation output. Further, Fritsch and Meschede (2001) examined the positive relationship between process R&D expenditure and firm size. This indicated that large firms devote a significant portion of their R&D on process innovation because process innovation improves product quality and/or enables introduction of completely new products. Likewise, Ornaghi (2006) investigated Spanish manufacturing firms and found that knowledge spillovers from R&D improve firms' innovation performance. Pradhan (2011) conducted a study of Indian manufacturing firms and found that R&D is an important determinant of SME performance. Interestingly, a number of researchers, including Hagedoorn and Wang (2012) and Berchicci (2013), categorized R&D into internal and external R&D in their studies on innovation performance.

2.2 External Research and Development

Firms can no longer rely on internal R&D and other internal capabilities (e.g., skills) to cope with the increasing cost of innovation, shorter product life cycles, and higher technological complexities (Berchicci 2013; Bergman 2010). This recent shift from closed to open innovation models has emphasized the role of external R&D activities. Through such network activities (i.e., R&D alliances with universities, suppliers, and research organizations), firms may increase their competitiveness and improve performance (Minarelli et al. 2013; Ahuja 2000; Cantner et al. 2010; Un et al. 2010). The common goal of external R&D is to develop new products and processes by reducing costs. Moreover, the potential benefits of such external networks are sharing risks and costs, shortening innovation cycles, and exploiting economies of scale (Hagedoorn 1990; Peltier and Naidu 2012; Colombo et al. 2011; Nieto and Santamaria 2010; Pullen et al. 2012). In addition, external R&D cooperation provides exchange of intangible (non-codified) knowledge by means of people-to-people contact and increases the market power of each cooperating partner (Teirlink and Spithoven 2013; Kinkel and Som 2010). Specifically, SMEs can overcome the challenges of resource constraints through R&D cooperation. Interestingly, the study of Teirlink and Spithoven (2013), based on 140 Belgian SMEs, found that micro enterprises rely more on R&D cooperation than other firm sizes.

Several studies concerning SMEs' financial resources suggest that they are more financially constrained than large firms (Abor and Biekpe 2007; Beck and Kunt 2006). Most SMEs typically do not have sufficient internal financial resources to undertake R&D projects directly. This indicates that lack of financial resources reduces the SMEs' innovation activities (Dundas 2006). One way to overcome this problem is through R&D collaboration with competitors, suppliers, and universities, which increases access to R&D spending and firm competitiveness (Hottenrott and Lopes-Bento 2012; De Jong and Vermeulan 2006). The lack of resources is a barrier to SMEs' innovation performance, but at the same time it is the primary motive for SMEs to search beyond their own boundaries for required knowledge and innovative ideas. In particular,

participating in R&D alliances allows firms to internalize technology spillovers, exploit economies of scale, combine complementary technological skills, and minimize the cost of R&D (Hottenrott and Lopes-Bento 2012). Moreover, SMEs can enhance their innovation performance by drawing upon external knowledge sources including other firms and research institutions (Chun and Mun 2012). Cooperative R&D agreements provide SMEs with opportunities to increase their absorptive capacity because such collaboration maximizes firms' internal stock of knowledge.

A study by Un et al. (2010) stated that R&D collaboration with universities and suppliers positively influences the firms' product innovation, but such collaboration with competitors appears to have a negative impact on product innovation. This indicates that not all R&D alliances positively influence product innovation. One disadvantage of R&D collaboration is transaction costs, especially to cooperate, manage, and control R&D activities (Becker and Dietz 2004). Nevertheless, the study of Chun and Mun (2012) on SMEs in the Republic of Korea suggested that R&D cooperation significantly improves the firms' product and process innovation. A similar finding was provided by Kinkel and Som (2010) related to the German mechanical engineering industry. In addition, Mukherjee et al. (2013) investigated R&D alliance formation in 854 German SMEs. They found that inter-firm trust was more likely to encourage R&D alliances because it mainly influence product innovations. Specifically, SMEs face more environmental uncertainty (i.e., uncertain costs and benefits of R&D), and trust between firms can minimize this problem. Likewise, Spithoven et al. (2013) investigated the open innovation practices in 967 Belgian SMEs. They argued that SMEs' reliance on external R&D significantly improved product innovation.

Concerning the link between internal and external R&D, Hagedoorn and Wang (2012) and Berchicci (2013) suggest that internal and external R&D have a complementary relationship at higher levels of in-house R&D intensity, while at low levels of in-house R&D intensity both internal and external R&D have a substitutability relationship. The trade-off between internal and external R&D influences firms' innovation output (Berchicci 2013). Similarly, a study by Bergman (2010) on Swedish firms found that internal and external R&D both have a positive impact on productivity and this may suggest a complementary relationship between the two types of R&D. Similarly, Lokshin et al. (2006) investigated 304 Dutch firms by using a dynamic linear panel model. They found that internal and external R&D have a complementary relationship. Additionally, Ceccagnoli et al. (2013) examined the complementary relationship between internal and external R&D of pharmaceutical firms and found that external R&D promotes innovation by fostering internal R&D activities. This finding suggests that firms with external R&D must also continue to undertake internal R&D. A similar finding is suggested by Piga and Vivarelli (2004) using Italian manufacturing firms. They argued that internal and external R&D have a complementary relationship, which implies that doing more of one increases the return on doing more of other. Likewise, Becker and Dietz (2004) conducted a study on 2,048 German manufacturing firms using simultaneous equations. They found that internal and external R&D have a complementary relationship. Their findings suggest that external R&D drives firms to invest more in the development of innovation. In other words, a firm with a sufficient internal R&D base has the absorptive capacity to benefit from external R&D activities.

The above literature review suggests four main hypotheses:

H1: *Internal R&D has a positive impact on SMEs' innovation performance.*
H2: *External R&D has a positive relationship with SMEs' innovation performance.*
H3: *Public support for innovation has a positive association with SMEs' innovation performance.*
H4: *Internal and external R&D have a complementary relationship.*

3. METHODOLOGY AND DATA

This section provides information related to the research context of this study. The innovation activities in Indian and Pakistani SMEs are compared, along with data sources.

3.1 Small and Medium-Sized Enterprises in India and Pakistan: Research Context

India and Pakistan are the two major economies of South Asia in terms of gross domestic product (GDP). They share a long border and are active members of the South Asian Association for Regional Cooperation. In 2013, India's GDP was about $1.9 trillion, while Pakistan's was much less at $232.3 billion. Despite tense diplomatic relations between the two countries, trade (informal) between the two countries is nearly $3 billion. SMEs in India contribute 17% to total GDP while the figure for Pakistan is around 40%. Indian SMEs employ nearly 15% of the national workforce (about 60 million people), account for 26 million enterprises, and contribute 45% of manufacturing output. In comparison, SMEs in Pakistan employ 75% of the nonagriculture workforce, account for 3.2 million enterprises, and contribute 30% of manufacturing output. Concerning R&D investment, India has the edge over Pakistan related to overall R&D expenditure, which is equal to 1.0% of GDP compared with 0.3% for Pakistan (World Bank 2012).

R&D investment is essential to expand absorptive capacity and national learning but the poor countries tend to do very little R&D due to their low human capital, lack of research infrastructure and the lower technological capacity of the private sector (Goni and Maloney 2014). For instance, Pradhan (2011) found that R&D intensity among Indian SMEs is very low, and lower than that of large firms. A shortage of funds is one of the important barriers to their technological competitiveness. In addition, Subrahmanya (2012) found that most Indian SMEs carried out incremental innovations that were driven by customer demands and confined to slight changes in product design and shapes. In comparison, a study by Subhan et al. (2014) suggested that Pakistani SMEs need to invest in knowledge-based resources (e.g., R&D, process innovation) if they hope to improve their innovation performance. Further, Pakistan has not yet developed an effective national system for improving R&D spending and other technological investment, especially in the biotech industry. Moreover, outdated technologies, lack of access to credit, high interest rates on lending, and the lack of government support are the major barriers faced by Pakistani SMEs (Berry 1998). Overall, the facts related to Indian and Pakistani SMEs suggest that a low level of R&D activity results in fewer innovations and that the lack of access to credit and the lack of an innovative culture are the major obstacles to innovation for SMEs.

3.2 Data Source

The data was obtained from the World Bank Enterprise database for 2013 under the title of "The World Bank Innovation Follow-Up." This survey was initially launched in 2011 to investigate the innovation performance of developing countries. The innovation data was available for both countries for the same year. The survey gathered information on the key innovation variables including R&D, product and process innovation, sources of financing for innovation, and aspects of organizational and marketing innovation. The survey covered 3,492 Indian firms and 696 from Pakistan. In both countries, over 75% of firms were engaged in manufacturing (textiles, tobacco,

chemicals, printing, electronics and machinery, and others) and over 15% in services (IT, wholesale trade, hotel and restaurants, transport, and others).

The majority of these firms surveyed were SMEs. This study uses dummy variables for firm size. The definition followed the guidelines from the World Bank Enterprise Survey instead of country-specific definitions. Small firms are defined as having 5–19 workers; medium-sized firms, 20–99 workers; and large firms 100 workers of more. In India, approximately 28% are small firms, 45% are medium-sized, and nearly 27% are large. For Pakistan, 44% are small firms, 35% are medium-sized, and 21% are large. Micro firms with fewer than 5 workers were not used in the analysis. The data was gathered from 23 Indian states and in Pakistan from three provinces—Punjab (54% of firms), Khyber Pakhtunkhwa (20.26%), and Sindh (13.36%)—and the capital city of Islamabad (12.79%).

3.3 A Comparison of Innovation Activities

India has higher internal R&D investment than Pakistan in plastics and rubber, machinery, chemicals, electronics, basic metals, and other sectors. Alternatively, Pakistani firms had higher R&D than India in food, textiles, chemicals, vehicles, retail trade, and others. This indicates that the industries in the two countries are different in terms of undertaking internal R&D. However, in both countries the R&D intensity is higher in manufacturing than in services. For comparative analysis, figures 1 and 2 provide the innovation activities of Indian and Pakistani SMEs.

As shown in Figure 1, approximately 46% of the 3,492 Indian SMEs surveyed undertook internal R&D compared with just over 9% of 696 Pakistani firms. This suggests that Pakistani SMEs are much less engaged in internal R&D. The level of external R&D undertaking is very low in both countries, suggesting there are poor alliances or collaboration with other firms and research institutions. Further, most (65%) of the Indian SMEs were engaged in product innovation, compared with only 22% of Pakistani SMEs. This information suggests that the low level of R&D by Pakistani enterprises results in low innovation output. A similar trend is found for process innovation; nearly 61% of Indian SMEs introduced process innovation compared with 9% of Pakistani SMEs. However, the patent and license output is low in both countries. This outcome could indicate that SMEs in both countries predominantly introduce incremental innovations. Overall, Figure 1 suggests that Indian SMEs are dominant in terms of carrying out internal R&D and product and process innovation compared with Pakistani SMEs.

SMEs in both countries rely mainly (over 70%) on internal sources of financing for their innovation activities (Figure 1). Interestingly, nearly 59% of Indian SMEs also financed their innovation through external borrowing from banks, but only 10% of Pakistani SMEs funded their innovation in this way. This suggests that Pakistani SMEs have substantially less access to external finance than Indian SMEs. Similarly, public support for innovation activities (R&D grants, subsidies, and tax credits) is low in both countries, albeit higher in India (8.0%) than in Pakistan (about 1.5%).

Figure 2 provides information on R&D and product and process innovation by firm size. Approximately 31% of small firms in India are engaged in R&D and nearly 46% of medium-sized firms. A much higher share of large firms, 63%, are engaged in R&D. In Pakistan, only 3% of small firms undertake R&D compared with 11% of medium-sized firms and 20% of large firms. Overall, the link between R&D and firm size indicates that large firms in both countries undertake more R&D than do SMEs. The level of R&D by SMEs is lower in Pakistan than India.

Figure 1: Innovation Activities in Indian and Pakistani Small and Medium-Sized Enterprises (%)

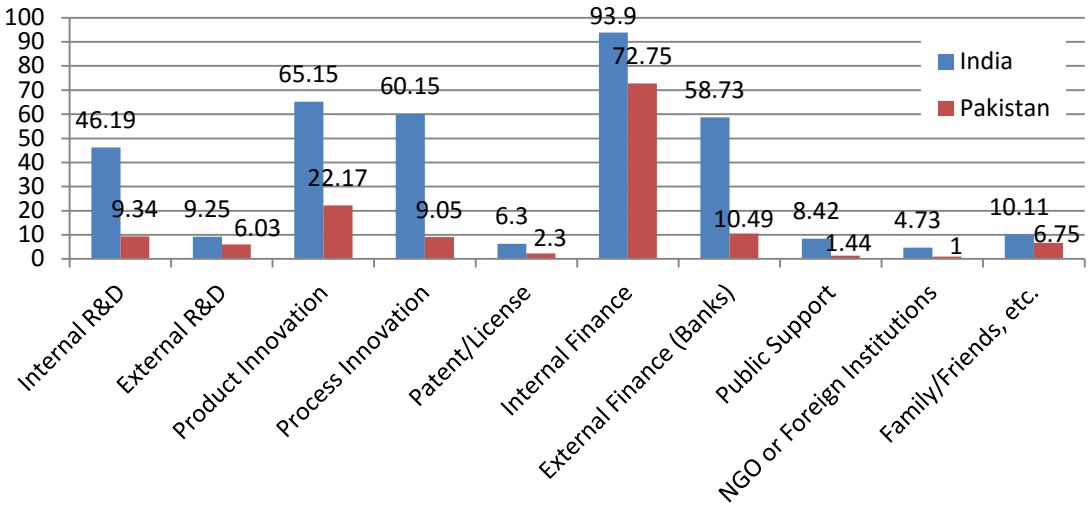
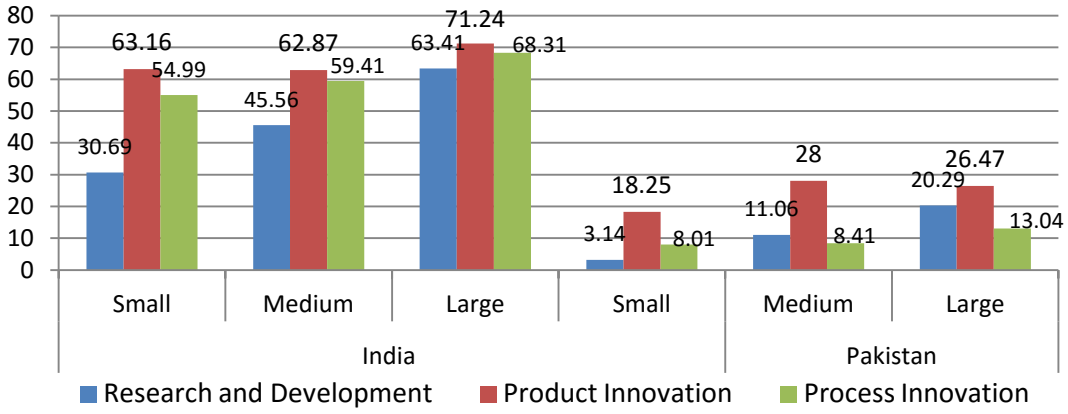


Figure 2: Research and Development and Product and Process Innovation by Firm Size, India and Pakistan (%)



In India, 63% of SMEs have introduced product innovations. However, 71% of large Indian firms generated product innovations and 68% undertook process innovations. In Pakistan, 18% of small firms have introduced product innovations compared with 28% of medium-sized firms and 26% of large firms. Process innovation is low at about 8%. Large firms are more engaged in innovation activities in both countries, which suggests they have better financial and knowledge resources. Pakistani SMEs have lower innovation capabilities than those in India.

3.4 Variables

The study uses two dependent variables, product innovation and process innovation, which are the key outputs of R&D and related activities (Conte and Vivarelli 2013; Fritsch and Meschede 2001; Pellegrino et al. 2014). Product innovation provides market leadership, broadens a firm's customer base, and increases the price buyers are willing to pay, while process innovation reduces a firm's average cost of production (Wolff and Pett 2006; Cohen and Klepper 1996; De Jong and Vermeulan 2006). While some studies (Hagedoorn and Cloodt 2003; Katila 2000; Liu 2009) used patent counts

and applications as a proxy for innovation output, this study prefers product and process innovation over patents as dependent variables for several reasons. First, it is not necessary that every innovation is patented; and second, many firms do not patent because of their reluctance to disclose information and secrecy can help to protect their innovations. Moreover, in developing countries patent usage is not very common due to financial constraints and the low quality of innovations (Ghoneim 2003).

The major independent variables of interest of this study are internal and external R&D. Two additional innovation input variables that are used are internal technology acquisition (investment in machinery, equipment, and software) and external technology acquisition (patents and licenses), which generally have a significant impact on firms' innovation performance (Silva et al. 2012; Crespi and Zuniga 2012). The other independent variables relate to firms' financial resources measured as internal funds, external bank finance, and public support (R&D subsidies and tax incentives). These three explanatory variables investigate the impact of different types of finance on firms' innovation output. Finally, firm size and age are added as control variables, the former as a dummy variable and the latter in logarithmic form.

4. ECONOMETRIC MODEL

4.1 Model Specification

A bivariate probit model is used to estimate the relationship between R&D and product and process innovations. This estimation method removes the sample selection bias and also presents more accurate parameters through the inclusion of non-innovative firms (Chun and Mun 2012). Alternatively, Heckman (1979) suggested a correction procedure (i.e., Heckit procedure) for sample selection bias by using continuous dependent variables. However, in this study, the dependent variables are predominantly discrete and the use of the inverse Mills ratio is not an appropriate choice. Moreover, the correlation coefficient between the two unobserved factors (residuals) from the two equations indicates the possible complementarities between the dependent variables. The model used is as follows:

$$y_{1i} = \begin{cases} 1 & if \;\; x_{1i}\beta_1 + e_{1i} > 0 \\ 0 & otherwise \end{cases} \quad \text{(a)}$$

$$y_{2i} = \begin{cases} 1 & if \;\; x_{2i}\beta_2 + e_{2i} > 0 \\ 0 & otherwise \end{cases} \quad \text{(b)}$$

where y_{1i} and y_{2i} are product and process innovations while, $e_{1i}\, and \;\; e_{2i}$ are error terms that are jointly normally distributed with correlation coefficient ρ=Corr (e_{1i}, e_{2i}). In other words, when ρ≠0 the null hypothesis is rejected and a bivariate probit model is the correct choice for estimation.

4.2 Empirical Results

Table 1 provides summary statistics and definitions of the variables used in the estimation (mean and standard deviation) for both countries. In addition, a correlation matrix is used to detect possible problems of multicollinearity (Appendix A1). Multicollinearity arises when some or all explanatory variables are highly correlated with each other and it is difficult to tell which variable is influencing the predicted variable (Koop 2004). However, the majority of correlations between variables are less

than 0.5. Only large firms' size category showed higher correlation (>0.6) with medium firms and it is dropped in the estimation.

Table 1: Variable Definitions and Descriptive Statistics

	India		Pakistan		
	$\bar{x}$	σ	$\bar{x}$	σ	Definition
Product innovation	0.651	0.476	0.228	0.420	Dummy coded 1 if firm introduced any innovative products or services in the last 2 years
Process innovation	0.605	0.488	0.090	0.287	Dummy coded 1 if firm introduced any innovative method of manufacturing processes or offering services
Internal R&D	0.461	0.498	0.093	0.291	Dummy coded 1 if firm conducted internal R&D for developing innovative products or services
External R&D	0.092	0.289	0.060	0.238	Dummy coded 1 if firm conducted external R&D undertaken by other firms or public or private research organization
Log age	2.743	0.745	2.940	0.627	Log (2014-Age)
Small	0.278	0.448	0.440	0.496	Dummy coded 1 if number of firm employees is 5–19
Medium	0.455	0.498	0.347	0.476	Dummy coded 1 if number of firm employees is 20–99
Large	0.266	0.442	0.211	0.409	Dummy coded 1 if number of firm employees is ≥100
Technology-acquistion1	0.633	0.482	0.178	0.382	Dummy coded 1 if firm spends on purchase of new equipment or software to develop innovative products or services
Technology-acquistion2	0.063	0.242	0.022	0.149	Dummy coded 1 if firm spends on license/patents or other type of knowledge
Internal finance	0.938	0.239	0.727	0.445	Dummy coded 1 if firm finances innovative activities from internal funds
External finance	0.587	0.492	0.104	0.306	Dummy coded 1 if firm finances innovative activities from banks
Public support	0.084	0.277	0.014	0.119	Dummy coded 1 if firm finances innovative activities through public support
Sector	0.780	0.414	0.837	0.369	Dummy coded 1 if firm is from manufacturing sector, otherwise zero

R&D = research and development, $\bar{x}$ = mean, σ = standard deviation.

4.2.1 R&D (Internal and External) and Product and Process Innovation

Table 2 provides information on the relationship between undertaking internal and/or external R&D and generating product and process innovation for India. The results suggest that firms undertaking internal R&D increase the probability of product innovation by 37% and process innovation by 21%. This outcome confirms our initial hypothesis and is in line with similar results from Stam and Wennberg (2009) and Gallie and Legros (2012). However, no statistical relationship is found between external

R&D and process innovation. One possibility for the latter result is that R&D might not be required for process innovation. This apparently suggests that undertaking external R&D is costly for Indian SMEs with regard to process innovation. The coefficients of technological acquisition show positive association to product innovation and to some extent process innovation as well. Thus, firms' decision to spend on machinery, equipment, licensing, and software generate innovation (Table 2). This result is similar to that of Silva et al. (2012).

Table 2: Bivariate Probit Estimation Analysis, India

	Product Innovation		Process Innovation	
Explanatory Variable	**Coefficient**	**Z-value**	**Coefficient**	**Z-value**
Internal R&D	0.3718[a]	7.65	0.1045[b]	2.14
	(0.0485)		(0.0489)	
External R&D	0.2144[b]	2.55	–0.0867	–1.10
	(0.0841)		(0.0789)	
Technology aquisition-1	0.3675[a]	7.38	1.0328[a]	21.20
	(0.0499)		(0.0487)	
Technology acquisition-2	0.1685[c]	1.80	0.1184	1.23
	(0.0936)		(0.0961)	
Log age	–0.0639[b]	–2.08	–0.0397	–1.28
	(0.0307)		(0.0311)	
Small firms	–0.1239[c]	–1.93	–0.1575[b]	–2.43
	(0.0642)		(0.0647)	
Medium firms	–0.2008[a]	–3.59	–0.1313[b]	–2.31
	(0.0559)		(0.0569)	
Internal finance	0.0264	0.28	–0.0494	-0.51
	(0.0947)		(0.0985)	
External finance	0.0299	0.64	0.2147[a]	4.51
	(0.0465)		(0.0476)	
Public support	0.6522[a]	6.62	–0.1073	–1.31
	(0.0985)		(0.0817)	
Sector	0.3912[a]	7.04	0.0774	1.35
	(0.0555)		(0.0574)	
Constant	0.3484[b]	2.45	–0.3249[b]	–2.24
	(0.1422)		(0.1447)	
Rho (ρ)	–0.3075[a]	10.75	–	–
	(0.0286)			
Wald Chi-square	819.14[a]		–	–

a = p<0.01; b = p<0.05; c = p<0.10.

Robust standard errors are in parentheses.

N = 3,486.

The coefficient of age shows a negative association to product innovation. This suggests that younger firms are more likely to generate product innovation than older firms. Firm size categories of small and medium present a negative relationship with product and process innovation,[2] which suggests that smaller firms are less likely to engage in innovation than large ones. This finding supports the Schumpeterian

[2] This study has also dropped large firms (as a dummy variable) for two reasons. First, large firms caused multicollinearity with other size bands. Second, this study specifically focuses on the analysis of SMEs. However, in the following models firm's size also used as continuous variable for comparison between small and large firms.

hypothesis that small firms are less innovative because of low economies of scale and weak access to skills and financial resources (Conte and Vivarelli 2013; Love and Roper 1999). Further, the parameter of external finance shows a positive relationship with process innovation. However, no statistical link is found between external finance and product innovation.

Public support for innovation activities through R&D grants, subsidies, and tax credits has a positive and significant impact on product innovation but not on process innovation. This result confirms the similar finding of Hottenrott and Lopes-Bento (2012). Lastly, the manufacturing sector is more likely to introduce product innovation.

Table 3: Bivariate Probit Estimation Analysis, Pakistan

	Product Innovation		Process Innovation	
Explanatory Variable	**Coefficient**	**Z-value**	**Coefficient**	**Z-value**
Internal R&D	0.1154 (0.2574)	0.45	–0.0664 (0.3366)	–0.20
External R&D	0.1015[c] (0.0572)	1.77	0.4433[b] (0.1663)	2.66
Technology aquisition-1	0.3395[b] (0.1593)	2.13	1.0154[a] (0.1749)	5.80
Technology acquisition-2	0.6580* (0.4109)	1.60	0.3973 (0.3552)	1.12
Log age	0.4957[a] (0.1104)	4.49	0.1954 (0.1267)	1.54
Small firms	0.0359 (0.1704)	0.21	–0.0546 (0.2187)	–0.25
Medium firms	0.3037* (0.1670)	1.82	–0.1721 (0.2091)	–0.82
Internal finance	0.8947[a] (0.1749)	5.11	0.6304[a] (0.2057)	3.06
External finance	–0.1996 (0.2055)	–0.97	0.1062 (0.225)	0.48
Public support	0.3141 (0.4828)	0.65	0.0390 (0.5459)	0.07
Sector	0.4040[b] (0.1982)	7.04	0.2886 (0.2501)	1.15
Constant	–3.3600[a] (0.4748)	–7.08	–2.8609[a] (0.5308)	–5.39
Rho (ρ)	0.6107[a] (0.0721)	8.47	–	–
Wald Chi-square	121.24[a]	–	–	–

a = p<0.01; b = p<0.05; c = p<0.10.

Robust standard errors are in parentheses.

N = 648.

Table 3 shows the results for Pakistan. Surprisingly, internal R&D shows no statistical association with innovation and therefore rejects the initial hypothesis. There are two possible explanations for this outcome. First, Pakistani SMEs do not undertake internal R&D because it is costly and risky. Second, Pakistani SMEs may not have the R&D-related capabilities (workforce skills) to conduct internal R&D. In contrast, external R&D does increase the probability of introducing product innovation by 10% (it was 21% for India). External R&D showed a strong association (nearly 44%) with process

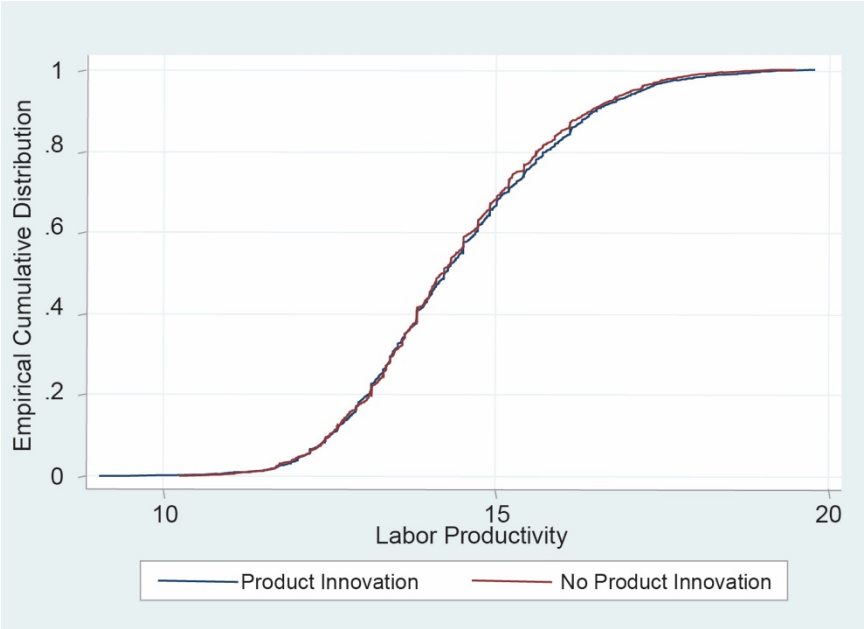
innovation (higher than India). This result suggests that Pakistani SMEs may overcome the high costs and risks and skill-related problems through R&D alliances. However, this effect is stronger for process innovation than for product innovation.

Technological acquisition has a positive and significant impact on product and process innovation, which is in line with the findings of Crespi and Zuniga (2012). The coefficient of age shows a positive association with product innovation, implying that older firms are more likely to introduce product innovation. Concerning the relationship between firm size and innovation, medium-sized firms show a positive association to product innovation. No relationship is found between firm's size and process innovation. Regarding internal sources of financing for innovation activities, internal finance is positively correlated with product innovation but it is not significant. For process innovation, the sign is negative and the variable is also insignificant. The parameter of external finance is also insignificant and may indicate that Pakistani SMEs are more externally constrained than Indian SMEs. The manufacturing sector is more likely to introduce product innovations than the services sector.

4.2.2 Productivity and Innovation

A number of researchers have found that innovation has a positive impact on productivity (Masso and Vahter 2011; Cassiman and Golovko 2007). These studies identified an endogenous relationship between innovation and productivity, although that endogeneity is beyond the scope of this study. Figures 3–6 compare the labor productivity of innovators to non-innovators for India and Pakistan.[3] For Indian firms that are product innovators (Figure 3), the labor productivity distribution coincides with that of non-product innovators. For Pakistan, the productivity of product innovators exceeds that of non-product innovators (Figure 5).

Figure 3: Productivity Difference by Product Innovation (India)



[3] Labor productivity is defined as a firm's total sales divided by the number of employees. Labor productivity is logged. Further, OLS regression has been used to investigate the relationship between productivity and innovation. However, a low R-square value (<0.05) and nonsignificant coefficients suggest that the use of the OLS method is not an appropriate choice.

Figure 4: Productivity Difference by Process Innovation (India)

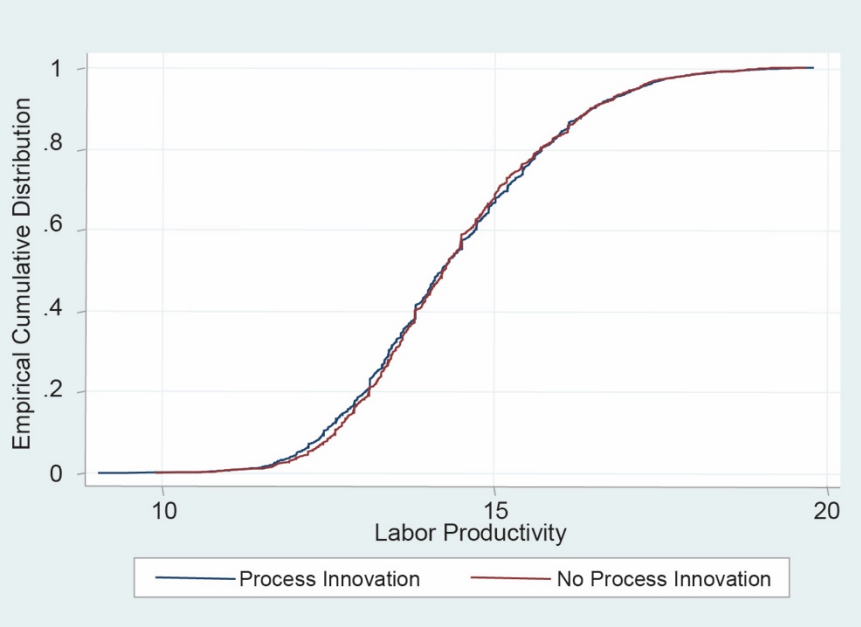
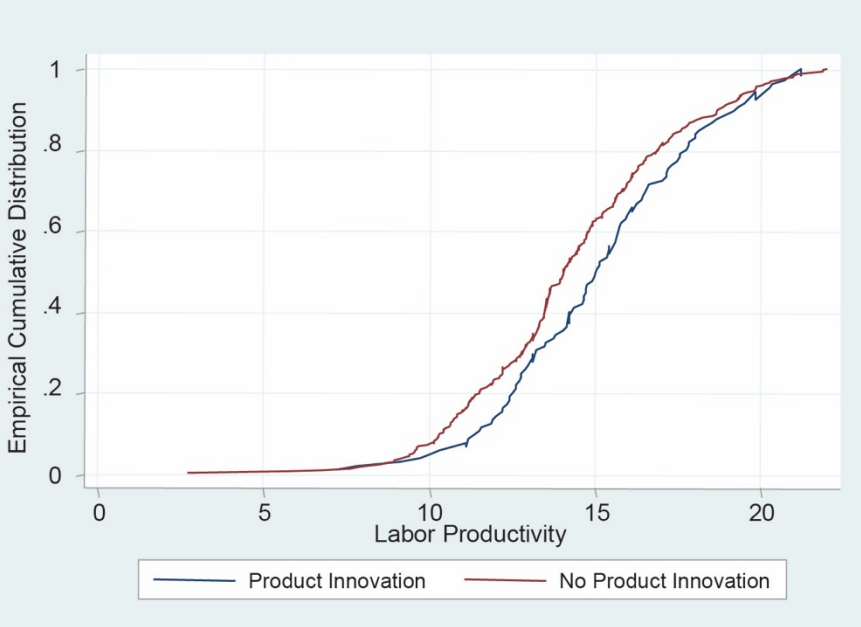


Figure 5: Productivity Difference by Product Innovation (Pakistan)



Labor productivity distribution for process innovators is coincided with non-process innovators for both India and Pakistan (see Figures 4 and 6). However, in Pakistan, the labor productivity distribution of process and non-process innovators is similar (Figure 6). The lack of information on other variables (e.g., materials, capital investment) has prevented the use of total factor productivity, which is a better indicator of productivity. Overall, these figures suggest that the productivity of product innovators has stochastic dominance over process innovators in Pakistan, while Indian firms showed no stochastic dominance for process innovators.

Figure 6: Productivity Difference by Process Innovation (Pakistan)

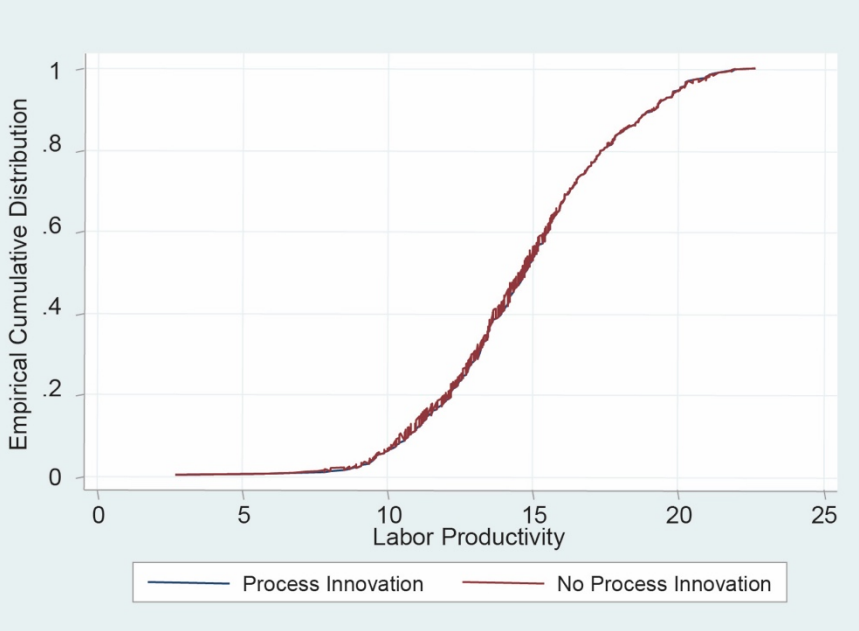


Table 4: Kolmogorov–Smirnov Test for Equality of Distribution Function

Innovation	Labor Productivity (Yes = 1)	Labor Productivity (No = 0)
Product innovation (India)	0.0293	–0.0115
Process innovation (India)	0.0198	–0.0351
Product innovation (Pakistan)	0.1209[a]	–0.0158
Process innovation (Pakistan)	0.1078	–0.0708

[a] Indicates null hypothesis rejected at 10% significance level.

Results of the Kolmogorov–Smirnov test for equality of distribution are provided in Table 4, which compares the labor productivity distribution of product and process innovators for the two countries. In the case of Pakistan, the labor productivity of product innovators stochastically dominates the non-product innovators and the null hypothesis of no productivity difference is rejected. This implies that product innovators tend to be more productive than non-product innovators only for Pakistani SMEs.

4.2.3 Complementary Relationship between Internal and External R&D

To estimate the final hypothesis on the complementary relationship between internal and external R&D, separate probit models have been estimated (Table 4). Several researchers have used R&D as the dependent variable (Pradhan 2011; Ornaghi 2006; Piga and Vivarelli 2004; Becker and Dietz 2004). Specifically, Piga and Vivarelli (2004) found that internal and external R&D are potentially endogenous. Internal R&D is correlated with the error term in the external R&D equation. In order to avoid this endogeneity problem, this study has used separate probit models for each dependent variable (internal and external R&D). This follows the method used by Becker and Dietz (2004) to estimate the complementarity between internal and external R&D. In the current study, internal R&D and external R&D are both discrete variables so the choice of a probit model is appropriate. In addition, firm size is introduced as a continuous variable (in logarithmic form) for two reasons. First, several researchers have used firm size as a continuous variable to avoid the possible multicollinearity between firm size

categories (e.g., Demirbas et al. 2011). Second, using the sign of the coefficient of firm size as a continuous variable allows for the comparison between small and large firms.

Table 5 reports the results of the probit estimations for India and Pakistan. The link test is used to see whether the model is adequately satisfied without omitted variable bias. The variable prediction squared has accepted the null hypothesis which shows that the model is correctly specified (Table 4).[4] In the first model, a 1% increase in external R&D raises the probability of internal R&D by 53%. Similarly, in the second, internal R&D has a positive and significant impact on external R&D. In both specifications, the parameters for internal and external R&D are highly significant (at the ρ<0.01 level). This outcome indicates the complementary relationship between internal and external R&D. External R&D motivates firms to undertake more internal R&D and expand the firms' technological capabilities. This result is in line with the findings of Ceccagnoli et al. (2013) and Becker and Dietz (2004) and confirms the prior expectation of their complementary relationship.

Table 5: Probit Model Estimation (Maximum Likelihood Method)

	India			
	Internal R&D (Model 1)		**External R&D (Model 2)**	
Explanatory Variables	**Coefficient**	**Z-value**	**Coefficient**	**Z-value**
Internal R&D	–	–	0.4606[a] (0.0678)	6.79
External R&D	0.5399[a] (0.0829)	6.51	–	–
Technology aquisition-1	0.5013[a] (0.0479)	10.45	–0.0549 (0.0689)	–0.80
Technology acquisition-2	0.3281[a] (0.0940)	3.49	0.2849[a] (0.1069)	2.66
Log age	0.0268 (0.0305)	0.88	–0.0458 (0.0413)	–1.11
Log size	0.2571[a] (0.0221)	11.61	0.2208[a] (0.0805)	2.74
Internal finance	0.4283[a] (0.0942)	4.55	–0.0370 (0.1278)	–0.29
External finance	0.0194 (0.0464)	0.42	0.1742[a] (0.0637)	2.73
Public support	–0.1188 (0.0833)	–1.43	0.0602 (0.1069)	0.57
Sector	0.5440[a] (0.0575)	9.45	0.0727 (0.0811)	0.90
Constant	–1.0096[a] (0.1420)	–7.11	–1.4454[a] (0.1921)	–7.52
Pseudo R^2	0.1148		0.0468	
Model Specification Test				
Predict hat	1.0015[a]	21.19	0.8241	0.91
Predict hat–square	0.0068	0.10	–0.0669	–0.19

continued on next page

[4] A link test uses the prediction square of the model and if the prediction square does have explanatory power (i.e., the coefficient has significant value), it means that the model is incorrectly specified. In other words, the choice of explanatory variables is not appropriate for estimation. In this case, the prediction square coefficients have insignificant values, which means the model is well specified.

Table 5 *continued*

Pakistan				
	Internal R&D (Model 3)		External R&D (Model 4)	
Explanatory Variables	**Coefficient**	**Z-value**	**Coefficient**	**Z-value**
Internal R&D	–	–	2.4019[a] (0.2677)	8.91
External R&D	2.4239[a] (0.2862)	8.46	–	–
Technology aquisition-1	0.3626[a] (0.1951)	1.86	0.3203[a] (0.1228)	2.60
Technology acquisition-2	1.2141[a] (0.4174)	2.91	0.1126 (0.4392)	0.26
Log age	0.06577 (0.1599)	0.41	–0.2618 (0.2130)	–1.23
Log size	0.2707 (0.2102)	1.29	1.7957[a] (0.4002)	4.49
Internal finance	0.8533[a] (0.2148)	3.97	0.2985 (0.2904)	1.03
External finance	0.1149 (0.2756)	0.42	0.2345 (0.3708)	0.63
Public support	0.3758 (0.7127)	0.53	0.6318[c] (0.3548)	1.78
Sector	–0.0289 (0.2396)	–0.12	0.6041 (0.4252)	1.42
Constant	–2.6540[a] (0.6191)	–4.29	–1.9740[b] (0.7919)	–2.49
Pseudo R^2	0.1468		0.1233	
Model Specification Test				
Predict hat	0.9605[a]	7.16	0.7357[a]	3.10
Predict hat–square	–0.0436	0.41	–0.1942	–1.21

a = p<0.01, b = p<0.05, c = p<0.10.

Robust standard errors are in parentheses.

N = 3,488 for India and N = 648 for Pakistan.

In addition, technology acquisition shows a positive association with internal R&D in the case of India (Table 5, model 1). This outcome indicates that firms' innovation expenditure is likely to increase the probability of undertaking internal R&D. However, in model 2 only one form of technology acquisition shows a positive association to external R&D. Overall, firm size shows a positive relationship with both internal and external R&D. This outcome suggests Indian and Pakistani SMEs are less likely to engage in R&D than large firms. This finding accords with the Schumpeterian notion that large firms are more innovative than small firms due to their economies of scale advantage.

Similarly, a positive relationship is found between internal and external R&D for Pakistan (Table 5). The relationship is much stronger for Pakistani firms than for those in India. Overall, the outcomes between internal and external R&D in Table 4 suggest that both variables have a complementary relationship. Increasing internal (or external) R&D by a factor of 1 increases the probability of increasing external (or internal) R&D by a similar magnitude. Furthermore, technology acquisition increases the probability of engaging in internal R&D. However, only model 4 shows a positive relationship between firm size and undertaking external R&D. This outcome implies that large firms

are more likely to undertake external R&D. The coefficient of internal finance shows that a 1% increase in internal finance is likely to raise internal R&D by 85%. This indicates that the majority of Pakistani SMEs rely on internal sources of finance for their innovation activities. Lastly, public support to innovation activities (e.g., R&D subsidies and grants) is likely to raise external R&D.

5. CONCLUSION

This study indicates that Indian SMEs undertake more internal and external R&D and introduce more product and process innovations than Pakistani SMEs. However, SMEs in both the countries exhibit weak R&D collaboration with other firms or research institutions. Moreover, SMEs were mainly engaged in incremental innovations due to the low level of patent protection. Similarly, public support for innovation activities in the form of R&D grants, subsidies, or tax credits are low for SMEs in both the countries. Furthermore, Pakistani SMEs are more constrained in terms of access to external finance than those in India. The majority of Pakistani SMEs relied on internal source of financing for innovation output (product/process). However, internal financing was not sufficient to undertake internal and external R&D. In comparison, Indian SMEs used both internal and external financing for accelerating their innovation output and were found marginally better in terms of undertaking R&D.

Regarding the estimation results, this paper reveals that SMEs engaged in both internal and external R&D may have significantly better innovation performance. This outcome was found stronger for Indian SMEs because Pakistani SMEs are reluctant to undertake internal R&D due to the high costs and risks associated with innovation efforts. Overall, the negative relationship between firm size and innovation output suggests that SMEs in both countries may be facing resource constraints. This result supports the finding of Schumpeter (1942) that small firms are less innovative—they have lower levels of R&D, are less capital intensive, and are more risk averse than large firms. In addition, the positive relationship between internal and external R&D implies a complementary relationship between these two types of R&D. This suggests the likelihood that investing in internal R&D would increase the probability of also engaging in external R&D, and vice versa. This result confirms the findings of other researchers.

The study provides important policy implications. First, the relationship between external R&D and innovation output indicates that small firms in both the countries require linkages with other firms and research institutions. Network relations are a good source for gaining complementary skills and absorptive capacity. Pakistani SMEs are at a specific disadvantage in terms of investment in internal and external R&D, and the lack of an R&D culture reduces firms' innovation performance. Policy instruments such as R&D grants from government agencies are more beneficial in increasing R&D investment and innovation output than R&D financing. It is difficult for SMEs to obtain R&D financing due to its risky nature (i.e., research can take a long time to generate results). Overall, the negative relationship between firm size and innovation output suggests that SMEs face resource constraints.

The results imply that specific policy measures might be provided through such institutions as the Small Industries Development Bank of India, other state financial institutions in India, the Small and Medium Enterprises Development Authority of Pakistan, and banks serving SMEs in Pakistan to remove the barriers to improving SMEs' innovation performance. In addition, such instruments as R&D grants and subsidies, a stronger R&D culture, the availability of external finance requiring less

collateral, and university–industry linkages may encourage SMEs to improve their innovation performance. The complementary relationship between internal and external R&D implies that business managers can utilize a balanced combination of R&D to increase innovation performance.

This study has several limitations. The unavailability of information on R&D expenditure, technological acquisition expenditure, and borrowing for Pakistani SMEs required the use of less precise dummy variables. Further, longitudinal data would have captured the effects of R&D more appropriately than cross-sectional data, as R&D is most often a long-term investment. A lower number of observations for Pakistan than for India also affected the accuracy of the estimates. The study can be extended to other South Asian countries to broaden the analysis of the innovation performance of SMEs.

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APPENDIX A1: CORRELATION MATRIX OF ALL VARIABLES (INDIA)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Product innovation	1.00													
2	Process innovation	(0.17)	1.00												
3	Internal R&D	0.14	0.13	1.00											
4	External R&D	0.07	0.00	0.14	1.00										
5	Log age	0.00	(0.01)	0.04	0.00	1.00									
6	Size 1	(0.02)	(0.07)	(0.19)	(0.06)	(0.06)	1.00								
7	Size 2	(0.04)	(0.02)	(0.01)	(0.01)	(0.01)	(0.50)	1.00							
8	Size 3	0.07	0.09	0.20	0.08	0.08	(0.37)	(0.61)	1.00						
9	Technology acquisition-1	(0.08)	0.40	0.22	0.02	(0.02)	(0.08)	(0.02)	0.10	1.00					
10	Technology acquisition-2	0.04	0.06	0.10	0.06	0.02	(0.05)	(0.01)	0.06	0.10	1.00				
11	Internal finance	0.02	(0.00)	0.07	0.00	(0.02)	(0.03)	0.05	(0.02)	(0.00)	(0.02)	1.00			
12	External finance	0.03	0.11	0.06	0.05	0.03	(0.10)	0.02	0.08	0.10	(0.07)	0.06	1.00		
13	Public	0.13	(0.06)	(0.03)	0.01	0.04	(0.02)	0.02	(0.00)	(0.13)	0.00	0.02	0.13	1.00	
14	Sector	0.14	0.08	0.20	0.04	0.14	(0.05)	0.05	0.01	0.04	0.12	0.07	0.02	0.07	1.00

( ) = negative number, R&D = research and development.

Size 3 showed higher correlation (>0.6). For Pakistan, the correlation matrix showed values lower than 0.5.